CLAIMS

What is claimed is:

1. A system for evaluating or calibrating a bubble detector, comprising:

a conduit adapted to pass a flow material therethrough;

a pump operatively coupled to the conduit to pump the flow material through the conduit;

a bubble-forming device operatively coupled to the conduit, the bubble-forming device being adapted to introduce bubbles into the flow material passing through the conduit; and

a bubble detector to be evaluated positioned to examine the bubbles in the flow material passing through the conduit.

2. The system, as set forth in claim 1, comprising:

an elevation device positioned to examine the bubbles in the flow material passing through the conduit.

3. The system, as set forth in claim 1, wherein the pump comprises a peristaltic pump.

4. The system, as set forth in claim 1, wherein the pump is capable of pumping the flow material through the conduit at a plurality of flow rates.

5. The system, as set forth in claim 1, wherein the bubble-forming device comprises:

a connecting device operatively coupled to the conduit;

a bubble-forming capillary adapted to be positioned within the connecting device in communication with the flow material passing through the conduit; and

a bubble-pumping device operatively coupled to the bubble-forming capillary, the bubble-pumping device adapted to deliver a bubble-forming material to the flow material in the conduit through the bubble-forming capillary to create bubbles in the flow material.

6. The system, as set forth in claim 5, wherein the capillary comprises:

a proximal portion operatively coupled to the bubble-pumping device and a distal portion slidably positioned within the connecting device.

7. The system, as set forth in claim 5, wherein the bubble-pumping device comprises a syringe.

8. The system, as set forth in claim 5, wherein the bubble-pumping device is adapted to deliver the bubble-forming material at a plurality of bubble flow rates and sizes.

9. The system, as set forth in claim 1, comprising:

a pulse dampener operatively coupled to the lumen between the pump and the bubble-forming device.

10. The system, as set forth in claim 1, wherein the flow material comprises a surfactant.

11. The system, as set forth in claim 2, wherein the evaluation device comprises:

a previously evaluated bubble detector having a known bubble detection resolution.

12. The system, as set forth in claim 2, wherein the evaluation device comprises:

an inspection device adapted to record bubbles formed by the bubble-forming device.

13. The system, as set forth in claim 12, wherein the inspection device comprises a camera operatively positioned proximate the connecting device.

14. A method of evaluating or calibrating a bubble detector comprising the acts of:

(a) pumping a flow material through a conduit;

(b) introducing bubbles into the flow material;

(c) examining the bubbles in the flow material with a bubble detector under evaluation; and

(d) detecting the bubbles in the flow material.

15. The method, as set forth in claim 14, wherein act (b) comprises the act of:

using a capillary to inject bubbles into the flow material.

16. The method, as set forth in claim 15, wherein the act of using a capillary comprises the act of:

slidably positioning the capillary within the flow material to adjust the size of the bubbles.

17. The method, as set forth in claim 15, wherein the act of using a capillary comprises the act of:

pumping a bubble-forming material through the capillary and into the flow material.

18. The method, as set forth in claim 14, wherein act (b) comprises the act of:

introducing a gas into the flow material to create the bubbles.

19. The method, as set forth in claim 14, comprising the act of:

mitigating pressure oscillations within the flow material.

20. The method, as set forth in claim 14, wherein act (c) comprises the act of:

using an ultrasonic probe to examine the bubbles in the flow material at a plurality of ultrasonic signal levels.

21. The method, as set forth in claim 14, wherein act (d) comprises the act of:

detecting the bubbles by visual inspection.

22. The method, as set forth in claim 14, wherein act (d) comprises the act of:

detecting the bubbles using a bubble detector having a known bubble detection resolution.

23. The method, as set forth in claim 14, comprising the act of:

comparing the examination of the bubbles in the flow material with the bubble detector with the detection of the bubbles in the flow material to calibrate the bubble detector.

24. The method of claim 23, comprising the acts of:

(a) calculating a calibration factor from the examination of the bubbles in the flow material with the bubble detector and the detection of the bubbles in the flow material; and

(b) applying the calibration factor to the bubble detector to calibrate the bubble detector.

25. The method, as set forth in claim 14, wherein act (a) comprises the act of:

pumping the flow material in the conduit at a plurality of flow rates.

26. The method, as set forth in claim 14, wherein act (b) comprises the act of:

altering the size of the bubbles.

27. The method, as set forth in claim 14, wherein act (b) comprises the act of:

altering a formation rate of the bubbles.

28. The method, as set forth in claim 24, wherein act (b) comprises the act of:

programming the calibration factor into a memory of the bubble detector.

29. A bubble detector comprising:

an ultrasonic transducer pair comprising a transmitting transducer and a receiving transducer, the ultrasonic transducer pair being positionable to sense bubbles in a fluid flow;

a transducer driver operatively coupled to the transmitting transducer to cause the transmitting transducer to deliver a pulsed ultrasonic signal across the fluid flow to the receiving transducer;

a signal conditioner operatively coupled to the receiving transducer to receive the pulsed ultrasonic signal from the receiving transducer, the signal conditioner conditioning the pulsed ultrasonic signal to produce a conditioned signal; and

a signal processor operatively coupled to the signal conditioner to receive the conditioned signal, the signal processor determining information correlative to bubbles in the fluid flow in response to the conditioned signal.

30. The bubble detector, as set forth in claim 29, wherein the pulsed ultrasonic signal delivered by the transmitting transducer comprises a frequency range of 3 MHz to 4 MHz and a pulse rate of about 3 KHz to 40 KHz.

31. The bubble detector, as set forth in claim 29, wherein the signal conditioner comprises:

an amplifier adapted to amplify the pulsed ultrasonic signal from the receiving transducer.

32. The bubble detector, as set forth in claim 29, wherein the signal conditioner comprises:

a filter adapted to filter the pulsed ultrasonic signal from the receiving transducer.

33. The bubble detector, as set forth in claim 29, wherein the signal conditioner comprises:

a detector adapted to detect the amount of ultrasonic energy of the pulsed ultrasonic signal received by the receiving transducer.

34. The bubble detector, as set forth in claim 33, wherein the signal conditioner comprises:

an analog-to-digital converter adapted to convert the amount of ultrasonic energy detected by the detector into a digital signal.

35. The bubble detector, as set forth in claim 34, wherein the signal processor comprises a buffer adapted to hold multiple digital signals.

36. The bubble detector, as set forth in claim 35, wherein a reduction in the digital signal as compared to previously recorded digital signals or an average of previously recorded digital signals is correlative to bubbles in the fluid flow.

37. The bubble detector, as set forth in claim 29, wherein the signal processor comprises a digital signal processor.

38. The bubble detector, as set forth in claim 37, wherein the digital signal processor is adapted to detect and count each bubble in the fluid flow.

39. The bubble detector, as set forth in claim 37, wherein the digital signal processor determines the size of each bubble in the fluid flow.

40. The bubble detector, as set forth in claim 37, wherein the digital signal processor determines the volume of each bubble in the fluid flow.

41. The bubble detector, as set forth in claim 40, wherein the digital signal processor converts the volume of each bubble in the fluid flow to a volume of each bubble when it reaches a patient.

42. The bubble detector, as set forth in claim 40, wherein the digital signal processor determines an accumulated volume of bubbles over a given period of time.

43. The bubble detector, as set forth in claim 29, wherein the signal processor initiates a stop signal in response to the determined information.

44. The bubble detector, as set forth in claim 43, wherein the signal processor initiates the stop signal in response to the determined information indicating that the volume of bubbles when they reach a patient exceeds a predetermined limit.

45. A method of detecting bubbles, comprising the acts of:

(a) transmitting a pulsed ultrasonic signal across a fluid flow;

(b) receiving the pulsed ultrasonic signal transmitted across the fluid flow;

(c) conditioning the received pulsed ultrasonic signal to produce a conditioned signal; and

(d) processing the conditioned signal to determine information correlative to bubbles in the fluid flow.

46. The method, as set forth in claim 45, wherein act (a) comprises the act of:

transmitting the pulsed ultrasonic signal at a frequency range of 3 MHz to 4 MHz and at a pulse rate of about 3 KHz to 40 KHz.

47. The method, as set forth in claim 45, wherein act (c) comprises the act of:

amplifying the received pulsed ultrasonic signal.

48. The method, as set forth in claim 45, wherein act (c) comprises the act of:

filtering the received pulsed ultrasonic signal.

49. The method, as set forth in claim 45, wherein act (c) comprises the act of:

detecting an amount of ultrasonic energy received by the receiving transducer.

50. The method, as set forth in claim 45, wherein act (d) comprises:

performing an analog-to-digital conversion to convert the amount of ultrasonic energy into a digital signal.

51. The method, as set forth in claim 50, wherein act (d) comprises the act of:

storing or averaging multiple digital signals.

52. The method, as set forth in claim 51, wherein act (d) comprises the act of:

detecting a reduction in the digital signal as compared to a previously stored digital signal or an average of multiple digital signals, the reduction being correlative to bubbles in the fluid flow.

53. The method, as set forth in claim 45, wherein act (d) comprises the act of:

detecting and counting the number of bubbles in the fluid flow.

54. The method, as set forth in claim 45, wherein act (d) comprises the act of:

determining the size of each bubble in the fluid flow.

55. The method, as set forth in claim 45, wherein act (d) comprises the act of:

determining the volume of each bubble in the fluid flow.

56. The method, as set forth in claim 55, wherein act (d) comprises the act of:

converting the volume of each bubble in the fluid flow to a volume of each bubble when it reaches a patient.

57. The method, as set forth in claim 55, wherein act (d) comprises the act of:

adding the volume of each bubble to determine an overall volume of bubbles in the fluid flow.

58. The method, as set forth in claim 45, comprising the act of:

initiating a stop signal in response to the determined information.

59. The method, as set forth in claim 45, comprising the act of:

initiating a stop signal in response to the determined information indicating that the volume of bubbles when they reach a patient exceeds a predetermined limit.

60. The method, as set forth in claim 45, wherein act (a) comprises the act of:

repetitively sampling a bubble in a fluid flow as the bubble passes through a predetermined section of a fluid passageway.